Tunnel Vision – Dynamic Peripheral Vision Blocking Glasses for Reducing Motion Sickness Symptoms

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Figure 1: Tunnel Vision glasses help the user deal with motion sickness. Left, the user can see through the glasses as usual; middle, the glasses start to block visual stimuli in the peripheral vision; right, if the user starts to move their gaze away from the center, the glasses return to their transparent state.

ABSTRACT

Motion sickness affects roughly a third of all people. Narrowing the field of view (FOV) can help to reduce motion sickness symptoms. In this paper, we present Tunnel Vision, a type of smart glasses that can dynamically block a wearer's peripheral vision area using switchable polymer dispersed liquid crystal (PDLC) film. We evaluate the prototype in a virtual reality environment. Our experiments (n=19) suggest that Tunnel Vision statistically significantly reduces the following Simulator Sickness Questionnaire (SSQ) related motion sickness symptoms without impacting immersion: "difficulty concentrating" ($F(2,35) = 4.121$, $p = 0.025$), "head feeling heavy" ($F(2,35) = 3.231$, $p = 0.051$) and "nausea" ($F(2,35) = 3.145$, $p = 0.055$).

CCS CONCEPTS

• **Human-centered computing** → **Mobile devices**.

KEYWORDS

Smart Glasses, Motion Sickness, Virtual Reality, Peripheral Vision

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1 INTRODUCTION

Have you ever felt motion sickness or experienced nausea while reading something in a moving train or car? This is actually a common symptom. Approximately one in three people are highly receptive to motion sickness, and most people become motion sick in extreme circumstances [8]. Mismatches between a user's perception of motion and their visual system are regarded as triggering factors of motion sickness.

This study aims to propose a dynamic peripheral vision adjusting system to enable us to be less sensitive to or less affected by fast-moving scenery [25] (e.g., train ride, roller coaster ride). We hypothesize that dynamically blocking parts of the peripheral vision during fast-moving scenes can reduce motion sickness symptoms. According to related studies, narrowed FOV could ease users' cybersickness while watching fast-moving and rotating scenes in VR [3, 9, 18]. Our dynamic peripheral vision blocking glasses can also reduce cybersickness while experiencing fast-moving scenery in VR without completely removing access to visual information from peripheral vision [1, 10, 20]. This user study is divided into two parts: the first is to determine if the proposed peripheral vision blocking glasses can reduce symptoms of cybersickness while seeing fast-moving scenery in a VR environment. The second is to evaluate if these switchable PDLC film glasses can reduce cybersickness without completely sacrificing visual information from peripheral vision.

We summarize the contributions of this paper as follows:

(1) We present Tunnel Vision, a smart glasses prototype that can dynamically block a user's peripheral vision.
(2) Our prototype can significantly reduce some simulator sickness symptoms (nausea, difficulty concentrating and head feeling heavy) in a VR experiment (n=19) while having little impact on immersion.
(3) We also discuss a first usage test during train rides for 2 users who are highly affected by motion sickness.

1.1 Related Work

In terms of preventing motion sickness, there are several works that suggest behavioral or food adjustments. Miller et al. evaluate acupressure and acustimulation bands in this regard [19]. Stewart et al. suggest that ginger smell and taste can have positive effects on individuals suffering from motion sickness [24].

The symptoms evoked by motion sickness are very similar and overlap with simulator sickness. Regarding motion and simulator sickness in VR and AR applications, studies often leverage a shrinking field of view (FOV) to help ease symptoms [5, 6, 9, 17, 18]. Most of the current methods are more or less a trade-off between experiencing motion sickness symptoms and impacting immersion. Besides, several researchers focus on assessing motion sickness using bio signals [15, 27].

Since the screen changes instantly, teleportation reduces the sensation of moving and suppresses simulator sickness [2, 13]. A study comparing the severity of sickness for steering (the user continuously perceives the scene along a path to the destination) with the severity for jumping reported significantly lower scores for jumping. In the same experiment, steering tended to be preferred for the task of allowing users to freely explore the VR space [26].

Some studies have minimized decreasing presence by dynamically controlling the FOV. They obtain the user's movement velocity and angular velocity and control the FOV accordingly to ensure a sense of presence while reducing simulator sickness [6]. The Simulator Sickness Questionnaire (SSQ) is a widely used tool to assess these symptoms [14].

We wanted to provide a wearable solution to the problem of motion sickness [16]. To the best of our knowledge, we are the first researchers presenting a wearable device that blocks part of the peripheral vision to reduce motion sickness in VR/AR and real life situations. Most other approaches are implemented in software. We see them as complimentary to our approach.

1.2 Approach and Hardware Design

In order to build a device that can narrow its user's FOV, especially one that prevents its user from seeing visual information via peripheral vision, we use a switchable film instead of an optical lens, known as polymer dispersed liquid crystal (PDLC) switchable smart film (see figure 2). Even when the film is in its transparent mode, it is not as clear as a regular optical lens. Due to this limitation, we cut out the area between both pupils. Regarding the cut out area, we measured 16 college students (8 male and 8 female) in advance and found their average interpupillary distance was 63.3 mm (SD = 3.3, MAX = 70, MIN = 58). Based on this data and actual experience with the glasses, we decided to cut out a horizontal elliptical area with a major axis of 8 cm. The participants seem to be comfortable in the setup if looking straight.

As the control system for changing between transparent and opaque mode, we use an Arduino compatible Pro Mini development board. Concerning its interactive design, we use two photo-reflective sensors to detect users' eye movements. Such sensors are widely used to detect changes in distance. Our eyelids, sclera and the area within the boundary of the iris, each have a different infrared reflectance, which enables us to detect eye movements. Regarding interactive logic, our visual stimulus (Epic Roller Coasters) shows the following message in its initial scene: "Focus here, if you feel motion sickness". So we can assume that if our participants feel sick, they can focus on any place without moving their eyes for 3.5 seconds, then the dynamic glasses' switchable PDLC film will become opaque to prevent its user from experiencing the fast-moving surrounding scenery via their peripheral vision. In comparison, if the users move their eyeballs, we assume that they feel well, then the film will be transparent to support them getting more visual information.

2 EXPERIMENTS

Our experimental protocol has three conditions. We use an ordinary lensless frame as the baseline condition. Condition two is wearing a frame with our dynamic peripheral vision blocking film while the dynamic clear-opaque mode is locked in its opaque state, which means the glasses work as FOV narrowed glasses. The third condition is wearing a frame with our peripheral vision blocking film while its clear-opaque mode is set to dynamic.

Participants and Recruitment: We recruited 19 participants in total: 13 participants identified as female and 6 as male. They were on average 25.1 years old (SD = 2.0, Min = 21, Max = 30). Seventeen of them reported they experienced light to strong motion sickness. Fifteen of them reported that they had experienced VR games before. All participants of our experiment were required to wear their contact lenses if they were nearsighted, to make sure all participants were able to see the fast-moving scenery as clearly as possible.

All participants joined with informed consent, the experimenter explained the experimental setup, they signed the consent form and could stop the experiment at any time. The experimental setup was approved by the ethics committee of Keio Media Design, Keio University.

Protocol and Conduction: As location for the experiment, we used a soundproof room (music studio) to keep potential noise from affecting the outcome. For showing the visual stimuli to the participants, we used an Oculus Quest 2 head-mounted display. As visual stimuli we used a VR game called Epic Roller Coasters [7] that we pre-installed on the Quest 2 headset. To make sure that participants watch the same contents at the same speed, we set up the game settings in advance (e.g., classical mode, dinosaur park, default roller coaster).

Instead of evaluating motion sickness directly, we used the SSQ [4, 21, 23]. Simulator and motion sickness are closely related. We

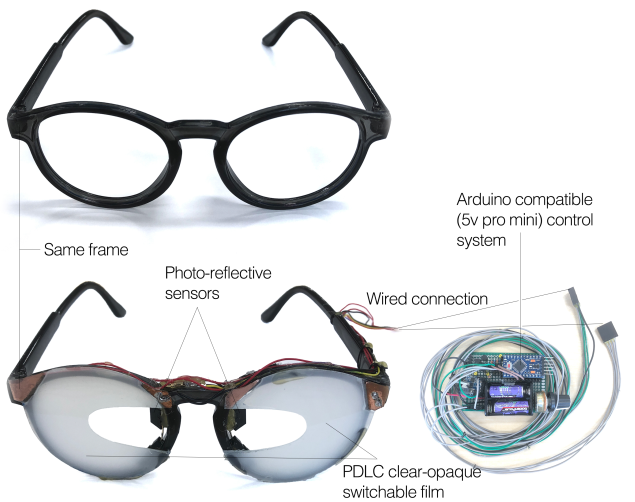

Figure 2: Above, lensless frame; below, frame plus dynamic peripheral vision blocking film and its control system.

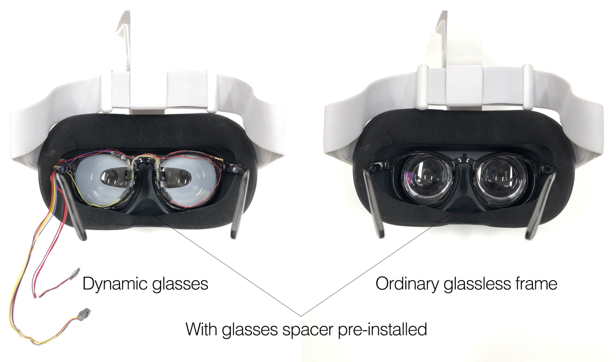

Figure 3: Left, Quest2 with dynamic glasses; right, Quest2 with ordinary lensless frame.

conducted our experiments in virtual reality to be more reproducible, and the SSQ is a standard method to evaluate motion sickness and similar symptoms in VR setups [9].

Before starting the roller coaster game in the VR headset, we first had participants answer questions (gender, age, if they have myopia, how often they experience motion sickness, how often they play VR games, how often they experience cybersickness). These questions are designed to find potential correlations between motion sickness levels and each individual's personal characteristics. After that, they were asked to answer the SSQ to reveal a person's present motion sickness level.

After the participant finished the first SSQ, we adjusted the Quest 2's interpupillary distance setting to match their interpupillary distance, which we had measured beforehand, ensuring that every participant was able to see the visual contents in the VR headset clearly.

We used a Latin square to decide in which order the glasses are chosen. Making sure that participants have no problem using both Quest 2 and our glasses, we pre-installed the glasses spacer of Quest 2. The way we set the lensless frame or the dynamic glass is like figure 3 indicates. When the setup of the headset (IPD setting, game settings, glasses setting) was finished, each participant was informed of the duration of each condition and told that they could stop the experiment at any time.

We recorded the game's running time on a Macbook Air laptop (duration using the described settings when not stopped early by the participant: 4 minutes 30 seconds). If participants stopped the first condition of their test, then we stopped the rest of the conditions after the same amount of time, which enabled us to compare the variations within the participants. When the game was finished, they were asked to finish another SSQ to reveal their present motion sickness status. At each stage of the experiment, participants were required to answer two SSQs, one before the game started and one after finishing the game. Between each condition, there was a break of 25 minutes. The participants were told they could do recovery activities during this break, but not ask for experiment-related details since we would answer questions related to our study after all experiments would be finished.

To examine the difference in immersion, we compared two conditions, one was wearing an ordinary lensless frame, the other was wearing clear-opaque peripheral vision adjusting glasses with dynamic mode activated. In this immersive comparison section, most of the procedures remained the same as before, for instance, the order we show stimuli to participants (counter balanced using Latin square). In the immersion comparison section, the participants were also required to answer one customised immersive experience questionnaire [11] after each condition. This is a widely used evaluation method to measure immersion [22]. Most of the questions remained the same as the original one. We used the roller coaster game as fast-moving scenery rather than treating it as a game, thus the questions which were not highly related to our test were removed, for example, "How much effort did you put into playing the game?", "To what extent did you find the game challenging?", or "How well do you think you performed in the game?". Additionally, participants did not have access to the Quest 2 controllers while the game was running.

This section aims to examine whether our peripheral vision blocking glasses can reduce the symptoms of motion sickness without sacrificing immersion while experiencing fast-moving scenery in a VR environment. Before participants put on the glasses, they were instructed on how to control them ("If you direct your gaze anywhere in your field of view and keep it there for 3.5 seconds without moving your eyes, the glasses will become opaque, and if you move your eyes, the glasses will become clear."). After they were able to successfully control the glasses, we helped them put on the Quest 2 and started the game. After each participant had finished the experiment, we conducted interviews to collect qualitative responses as well as to get a deeper understanding of their physiological and mental reactions while playing.

3 RESULTS

Figure 4 indicates that in most cases wearing our prototype with its dynamic clear-opaque mode on or off resulted in less severe motion sickness symptoms compared to wearing lensless glasses, except for "headache" and "increased salivation", in which the "dynamic clear-opaque mode on" condition had the lowest score. In other words, using peripheral vision blocking glasses significantly

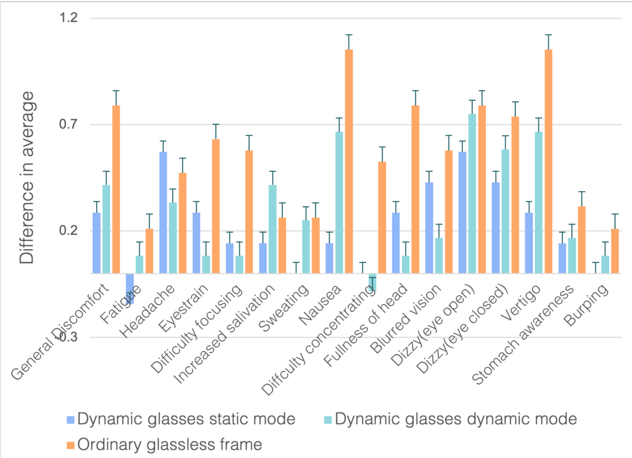

Figure 4: SSQ score difference (scores after the experiment minus scores before) comparing the three conditions (static blocking, dynamic blocking and lensless frame)

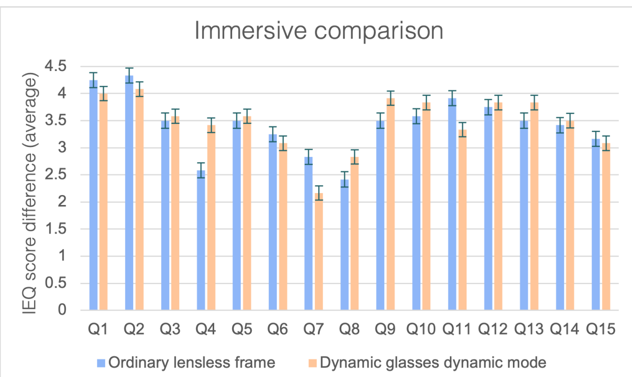

Figure 5: Immersion comparison between lensless frame and dynamic peripheral vision blocking glasses

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reduced almost all motion sickness symptoms listed in the SSQ compared to using a lensless frame. In particular, there was a statistically significant difference between groups in the case of "difficulty concentrating" ($F(2,35) = 4.121$, $p = 0.025$) along with "fullness of head" ($F(2,35) = 3.231$, $p = 0.051$) and "nausea" as determined by one-way ANOVA ($F(2,35) = 3.145$, $p = 0.055$).

In terms of immersion difference (average), the results are as figure 5 represents: Questions 1, 2, 6, 11, and 15 show a reduced immersion score when compared to the condition of wearing lensless glasses. On the contrary, questions 3, 4, 5, 8, 9, 10, 11, 13, and 14 show increased scores. However, the result of the t-test shows that there were no statistically significant differences between the lensless condition ($M = 2.6$, $SD = 1.2$) and the dynamic clear-opaque switchable glasses condition ($M = 3.4$, $SD = 1.1$); $t(22) = -1.8$, $p = 0.083$. That is the lowest p value within our immersion comparison result. Meanwhile, the statistical significance of the rest of the options are all above 0.2. This indicates that there is no statistically significant immersive difference between the two conditions (wearing a lensless frame and peripheral vision blocking glasses).

Regarding qualitative feedback, some participants mentioned that when they used the dynamic clear-opaque glasses, the feeling

To what extent
1. did the game hold your attention?
2. did you feel you were focused on the game?
3. did you lose track of time?
4. did you feel consciously aware of being in the real world?
5. did you forget about your everyday concerns?
6. were you aware of yourself in your surroundings?
7. did you notice events taking place around you?
8. did you feel the urge at any point to stop and see what was happening around you?
9. did you feel that you were interacting with the environment?
10. did you feel as though you were separated from your real-world environment?
11. did you feel that the game was something you were experiencing, rather than something you were just doing?
12. was your sense of being in the environment stronger than your sense of being in the real world?
13. were you interested in seeing how the events would progress?
14. did you enjoy the graphics and the imagery?
15. Would you like to repeat the experience?

Table 1: Glossary of figure 5; immersion questionnaire questions (Q1-Q15), some edited for brevity to fit the table, see Jennett et al. for details [12].

of discomfort occurred at a relatively smooth rising curve, which left them with more cognitive resources to see and recognize more visual contents in the VR environment than when they used the lensless glasses.

4 APPLICATION CASE

In addition to the described experiment, we conducted a short use case test with two users who had reported a very high susceptibility to motion sickness during their regular commute to work. They wore the static version (narrow FOV) of the glasses and turned it on for the 20 min train ride. Both users reported lower motion sickness symptoms using the system and wished to use the system regularly. One user found the clear version of the glasses slightly distracting (due to the type of PDLC used). The PDLC is not completely transparent even when activated. This will be addressed in the next iteration of the glasses.

5 CONCLUSION AND FUTURE WORK

Our study presents a potential method to reduce motion sickness symptoms while having less impact on immersion. It may fit real-life scenarios as well since its portable design was not exclusively created for use in a VR environment. Our experimental results show that there was a statistically significant difference in the following SSQ items without impacting immersion scores.

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